REMARKS

Upon entry of this amendment, claims 1, 3 and 5 are all the claims pending in the application. Claims 2 and 4 have been canceled by this amendment, and claim 5 has been added as a new claim. No new matter has been added.

Applicant notes that a number of editorial amendments have been made to the specification and abstract for grammatical and general readability purposes. Due to the number of changes made, a substitute specification and abstract are submitted herewith. No new matter has been added. Also enclosed is a marked-up copy of the original specification and abstract showing the changes incorporated into the substitute specification and abstract.

I. Claim Rejections under 35 U.S.C. § 101 and § 112, second paragraph

Claims 3 and 4 have been rejected under 35 U.S.C. § 101 and § 112, second paragraph. In particular, on page 2 of the Office Action, the Examiner has indicated that claims 3 and 4 provide "for the use of the better (sic), but that since the claim does not set forth any steps involved in the method/process, it is unclear what method/process applicant is intending to encompass" and that claims 3 and 4 result in an "improper definition of a process" (emphasis added). Applicant respectfully disagrees with the Examiner's position.

In particular, Applicant points out to the Examiner that claim 1, from which claim 3 depends, is not a method claim. Instead, claim 1 is clearly directed to a device for removing membranous lead sulfate. As such, Applicant respectfully submit that the Examiner's above-noted position regarding the lack of steps in claim 3 and 4 is irrelevant since the claimed invention is directed to a device, and not a method.

Also, for the Examiner's reference, Applicants point out that MPEP 608.01(n)(III) sets forth that the "test as to whether a claim is a proper dependent claim is that it shall include every limitation of the claim from which it depends (35 U.S.C. 112, fourth paragraph) or in other words that it shall not conceivably be infringed by anything which would not also infringe the basic claim."

In view of the foregoing, Applicant respectfully submit that claim 3 is in compliance with 35 U.S.C. 101 and 35 U.S.C. 112, second paragraph. Accordingly, Applicant kindly requests that the rejection be reconsidered and withdrawn.

II. Claim Rejections under 35 U.S.C. § 103(a)

Claims 1-4 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Bynum et al. (US 2001/0019257) in view of Rippel (US 3,808,481).

Claim 1, as amended, is drawn to a device for removing membranous lead sulfate deposited on electrodes of a lead-acid battery, wherein a negative pulse current having a short pulse width T of less than 1 μs, a pulse number of the order of 8000 to 12000 per second, and a current value in a range of 10 to 120 mA, is outputted from the device to bring about a conductor skin effect, so as to dissolve a surface layer part of the membranous lead sulfate deposited on the electrodes of the lead-acid battery. Applicant respectfully submit that the combination of Bynum and Rippel does not teach or suggest at least the above-noted features recited in claim 1.

With respect to Bynum, Applicant notes that this reference discloses a device for removing lead plate sulfate deposits on a lead acid battery by generating a series of pulses having a frequency in a range of 6 to 16 KHz (see Abstract and paragraph [0055]).

With respect to Rippel, Applicant notes that this reference discloses a Schmidt drive circuit 64 for generating a pulse signal having a rise time of about 0.1 microseconds, a current of 1 amp, and a voltage of 12 volts (see col. 10, lines 55-57; col. 11, lines 29-31 and Fig. 13).

Based on the foregoing descriptions, Applicant notes that while Bynum discloses a device for removing lead plate sulfate deposits on a lead acid battery by generating a series of pulses having a frequency in a range of 6 to 16 KHz, and that Rippel discloses the use of a circuit that generates a pulse signal having a <u>rise time of about 0.1 microseconds</u>, a current of 1 amp, and a voltage of 12 volts, that Bynum and Rippel, either alone or in combination, do not disclose or in any way suggest the above-noted features recited in amended claim 1 which set forth that a <u>negative</u> pulse current having a short <u>pulse width T of less than 1 μs</u>, a <u>pulse number of the order of 8000 to 12000 per second</u>, and a <u>current value in a range of 10 to 120 mA</u>, is outputted from the device to bring about a <u>conductor skin effect</u>, so as to dissolve a surface layer part of the membranous lead sulfate deposited on the electrodes of the lead-acid battery.

In view of the foregoing, Applicant respectfully submits that the combination of Bynum and Rippel does not render obvious the above-noted features recited in amended claim 1. Accordingly, Applicant submits that claim 1 is patentable over the cited prior art, an indication of which is kindly requested. Claim 3 and new claim 5 depend from claim 1 and are therefore considered patentable at least by virtue of their dependency.

III. Conclusion

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited.

If any points remain in issue which the Examiner feels may best be resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

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DEVICE FOR REMOVING LEAD SULFATE FILM FORMED IN LEAD-ACID BATTERY

TECHNICAL FIELD

This invention relates to a device for removing membranous lead sulfate ($PbSO_4$) formed on electrodes of a lead-acid battery due to sulfation.

BACKGROUND ART

Sulfation has so far remained a significant problem in a lead-acid battery. ~~The sulfation~~Sulfation is a phenomenon in which lead sulfate ($PbSO_4$), which is formed by a discharge of a lead-acid battery, precipitates on polar plates of the battery because of ~~vibration~~ variation or fluctuation of discharging ~~condition~~ conditions or an ambient temperature at which the battery is left to stand.~~, consequently~~ Consequently, ~~to develop to~~ a nonconducting film layer develops on the plates. This phenomenon may possibly cause an increase in internal resistance leading to performance deterioration of the battery or an inability to use the battery.

In order to curb the growth of the aforementioned lead sulfate formed in a film or membrane, the discharging conditions, temperature, vibration and other factors must be controlled with the greatest possible care. However, it is nearly impossible to have a user consistently render attention to the operative conditions of the battery. Thus, there has been a great need for a device capable of reestablishing the function of the lead-acid battery by removing the membranous lead sulfate deposited on the polar plates.

There has been conventionally known a device for removing the membranous lead sulfate by applying a pulse current to the battery to generate electroconvulsive shock between the polar plate and the membranous lead sulfate deposited on the polar plate.

As one example of the conventional devices of this kind, a battery activating device, which incorporates a circuit for generating a pulse current for exfoliating lead sulfate deposited on the polar plates of the lead-acid battery, is disclosed in Japanese

Patent Application Publication No. 2000-156247(A).

Also, in Japanese Patent Application Publication No. 2000-323188(A), there is disclosed a conventional lead-acid battery activating method ~~featured in that~~wherein a charging pulse current having larger electric quantity than a discharging pulse current is given immediately after applying the discharging pulse current. In this publication, there is a disclosure that the electric quantity of the discharging pulse current is over 0.1 C and the pulse width thereof is 0.0001 sec. to 1 sec.

The other analogous arts are disclosed in Japanese Patent No. 3079212 and Japanese Patent Application Publication No. 2000-40537(A).

The conventional arts thus disclosed all ~~have a mere function of~~merely physically ~~exfoliating~~ exfoliate the membranous lead sulfate from the polar plate, thus ~~to~~ temporarily ~~renovate~~ renovating the lead-acid battery. That is, ~~such a mere~~merely ~~measure of~~ physically exfoliating the membranous lead sulfate has a fundamental problem ~~such~~ in that lead sulfate flakes exfoliating away in consequence of applying the pulse current fall onto the peripheries of the lower parts of the polar plates or are suspended without dissolving in electrolytic solution in the battery, ~~consequently to be~~ and are again deposited ~~to~~ on the polar plates of the battery during discharging.

Besides, because the exfoliated lead sulfate flakes do not quickly dissolve in the electrolytic solution, ~~thus to keep~~ the specific gravity of the electrolytic solution is kept low, and the battery suffers from the disadvantage of being irrecoverable to the normal value. To bring the specific gravity of the electrolytic solution back to the normal value, dilute sulfuric acid must be supplied into the battery.

The conventional devices have a further disadvantage in that the exfoliated lead sulfate flakes sunk onto the peripheries of the lower parts of the polar plates are gradually dissolved into the electrolytic solution after supplying the dilute sulfuric acid into the battery, consequently ~~to elevate~~ elevating the specific gravity of the electrolytic solution in excess, resulting in damaging the polar plates ~~to~~ and a decrease in the life of the lead-acid battery.

Furthermore, there are disadvantageous cases in which the polar plate ~~getting~~ gets thinner ~~are~~ due to sometimes being exfoliated along with the falling lead sulfate

flakes, consequently ~~to decrease~~ decreasing the surface area of the polar plate producing a chemical reaction, ~~with~~ the result of which is that sufficient electric power required ~~in use~~ cannot be outputted from the battery. There is ~~one other~~another problem in ~~which~~ that the pulse current applied for removing the lead sulfate inevitably emits noise to the outside environment.

In ~~the~~ light of the foregoing problems brought about by the conventional arts, the present invention seeks to provide a novel device capable of removing membranous lead sulfate deposited on electrodes of a lead-acid battery by dissolving the membranous lead sulfate on the electrodes into fine particles without causing the membranous lead sulfate to fall off or be suspended in the electrolytic solution, so that the performance of the battery can be recovered to prolong the battery life.

The present invention further seeks to provide a novel device capable of removing membranous lead sulfate without damaging the electrodes and emitting noise to the outside environment.

~~DISCLOSURE~~ SUMMARY OF THE INVENTION

To attain the objects as described above according to the present invention, there is provided a device for removing membranous lead sulfate deposited on electrodes of the lead-acid battery due to sulfation by using a phenomenon bringing about a conductor skin effect of intensively dissolving the surface layer of the membranous lead sulfate deposited on the electrodes with the pulse current having a short pulse width, ~~which~~ the device ~~is~~being attached to a lead-acid battery and provided with a voltage detector, a reference voltage generator, a voltage comparator, an oscillator, an amplifier, a waveform shaping circuit, a negative pulse generator, and an electrifying indicator.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram of a device for removing membranous lead sulfate according to the present invention.

FIG. 2 is a waveform diagram showing currents at the points of A, B and C in FIG. 1.

FIG. 3 is an illustration showing one practical example of the device of the invention in use.

FIG. 4 is an illustration showing another practical example of the device of the invention in use.

FIG. 5 is a graph showing the results of performance measurements of the device in Embodiment 1 of the invention.

~~BEST MODE FOR CARRYING OUT AN~~ DETAILED DESCRIPTION OF THE INVENTION

To resolve common issues suffered from the conventional methods as described above, the present invention provides a device for removing lead sulfate deposited in a film or membrane on electrodes of the lead-acid battery due to sulfation. The device of the invention is mounted to a lead-acid battery and provided with a voltage detector, reference voltage generator, voltage comparator, oscillator, amplifier, waveform shaping circuit, negative pulse generator, and electrifying indicator. The device of the invention is featured by the use of a phenomenon bringing about a conductor skin effect of intensively dissolving the surface layer of the membranous lead sulfate deposited on the electrodes of the battery with the pulse current having a short pulse width.

According to the invention noted above, the lead sulfate formed in a film or membrane on the electrode of the lead-acid battery is sequentially dissolved into lead ion and sulfate ion as the result of concentration of electrical charge into the surface layer (skin depth) of the lead sulfate, which is caused by applying a pulse current having a pulse width which is so short as to give rise to a conductor superficial effect (skin effect) on the electrode with the membranous lead sulfate.

The device for removing membranous lead sulfate deposited on the electrodes of the lead-acid battery according to the invention is further featured by using the pulse current with a pulse width of less than 1 μs.

According to the device noted above, the pulse width of the pulse current to be applied to the electrodes can be made appropriate so as to effectively dissolve only the surface layer part of the membranous lead sulfate in membrane on the electrodes

without damaging the electrodes. Furthermore, because the pulse current applied to the device of the invention is very faint in intensity, no noise is emitted to the outside environment.

The device of the invention is further featured by making use of the electricity generated by the lead-acid battery as a power source for removing the membranous lead sulfate deposited on the electrodes of the battery.

According to the device using the electricity generated by the lead-acid battery as the power source for removing the membranous lead sulfate in itself, deposition of the lead sulfate onto the electrode can be effectively prevented.

The present invention will be described in detail hereinafter.

One embodiment of the circuitry of the device for removing the membranous lead sulfate according to the invention is shown in FIG. 1. The device of FIG. 1 comprises a voltage detector, reference voltage generator, voltage comparator, operation/nonoperation switch, oscillator, amplifier, waveform shaping circuit, negative pulse generator, and electrifying indicator. The operation/nonoperation switch serves to ~~switching~~ switch on or off the device and therefore is not indispensable for the device of the invention.

In FIG. 2, the waveforms at the points A, B and C in FIG. 1 are illustrated. In the device, a negative pulse current with a pulse width, which is so short as to give rise to the conductor skin effect, is brought about at the point C and applied to the lead-acid battery, ~~consequently~~ so as to dissolve the membranous lead sulfate deposited on the electrode into fine particles.

The conductor skin effect, herein, is a phenomenon in which ~~the~~ high-frequency current is localized in the surface layer of a conductor and does not penetrate deep into the conductor. With the conductor skin effect, the electrical charge is concentrated in the skin depth defined by the pulse width, so that the surface layer of the membranous lead sulfate can be sequentially dissolved into fine particles. Particularly, the lead sulfate is dissolved in order from the pointed tips of crystallized protuberances thereof.

Hence, unlike the conventional devices of this type, the device of the present invention can prevent the lead sulfate deposit on the ~~electrode~~ electrodes from exfoliating or falling off in clusters. ~~and~~ The lead sulfate is ~~suspending the lead sulfate~~ dissolved in fine particles and is prevented from becoming suspended in an electrolytic solution of the battery. ~~,~~ The lead sulfate may also be prevented frm returning to ~~remaining~~ the crystallized state.

The pulse current with a pulse width, which is so short as to give rise to the conductor skin effect, is very faint in intensity, and therefore, does not damage ~~to~~ the electrodes. Besides, the device of the invention has an advantage of producing little noise, ~~thus~~ so as not to affect the outside environment adversely.

Furthermore, the device has a function of suppressing generation of Joule heat, thus ~~to~~ preventing the electrodes from deforming and the battery from drying due to heat.

The pulse width of the pulse current outputted from the device may be determined in a range capable of bringing about the conductor skin effect. To be more specific, the pulse width may preferably be of less than 1 μs, particularly, in the range of 0.1 μs to 1 μs. The surface thickness calculated with the pulse width in the range specified herein is to come to the order of 0.01 mm, so that the electrical charge can be concentrated on the surface part without permitting the electrical charge to penetrate into the inside of the membranous lead sulfate deposit.

The pulse current with a pulse width of over 1 μs is ineligible because it causes thermal oscillation in a boundary face between the membranous lead sulfate deposit and the electrode, consequently ~~to permit~~ permitting the lead sulfate deposit on the electrodes to exfoliate and fall off.

With increase of pulse number of the pulse current to be applied, a rate of dissolving the membranous lead sulfate deposited on the electrodes is increased, but there is a case where heat is generated. Hence, this condition must be taken into account to determine the pulse number. Concretely speaking, it is preferable to determine the pulse number of the pulse current to be of the order of 8000 to 12000 per second.

The pulse current with excessively small voltage and current values makes it impossible to dissolve the membranous lead sulfate. Inversely, the pulse current with excessively large voltage and current values generates heat bringing about an adverse affect. Hence, this condition must be taken into account to determine the voltage and current values of the pulse current to be applied. To be more specific, it is preferable to determine the voltage and current values to be in the ranges of 12 to 108 volts and 10 to 120 mA. However, the optimum values, which depend on the pulse width and pulse number, should not be understood as limitative.

The power source for the device shown in FIG. 1 may be replaced with an external power supply, but it is desirable to use the lead-acid battery ~~in~~ itself to which the device of the invention is attached. Constant use of very small electric current generated by the lead-acid battery can effectively prevent the lead sulfate from being deposited onto the electrode of the battery.

The device mentioned above can be mounted on the lead-acid battery by being merely connected to the battery or in the other manner selected properly. As one example in a passenger car, bus or truck, a cigarette lighter's socket can be used as illustrated in FIG. 3. Alternatively, terminals shown in FIG. 4 may be brought in direct connection to the lead-acid battery by use of screws.

It is desirable to charge the lead-acid battery while or after applying the pulse current to the battery. By charging the battery, lead ~~ion~~ ions being resoluble by the pulse current ~~resolves~~ resolve ~~itself to recover~~and are recovered as an electrode of lead or lead dioxide. As a result, the specific gravity of the electrolytic solution of the battery turns back to its original optimum value, thus ~~to~~ swiftly ~~recover~~ recovering the performance of the battery. This function of effectively removing the lead sulfate from the electrodes of the lead-acid battery could be eventually achieved by the present invention enabling the surface part of the membranous lead sulfate to be dissolved into fine particles, but cannot be materialized by any conventional removing method using electric shock for exfoliating the lead sulfate from the electrodes because the crystallized lead sulfate fragments exfoliated by the electric shock are again deposited onto the electrodes even by charging the battery.

In the case of charging the battery while applying the pulse current, the

membranous lead sulfate ~~deposit~~ deposits on the electrodes are constantly dissolved and resolved, thus ~~to suppress~~suprressing growth of the sulfation, ~~with~~ the result of which is that the performance of the lead-acid battery can be maintained over a long period of time.

It is effective to repeatedly perform a course of processes of applying the pulse current to the lead-acid battery having the electrodes onto which the lead sulfate is deposited to degrade the performance of the battery and then charging the lead-acid battery. Consequently, the lead sulfate deposited on the electrode resolves from the surface layer part thereof to turn into a sponge-like state, thus ~~to increase~~increasing the specific gravity of the electrolytic solution in proportion to the time of applying the pulse current, so that the performance of the lead-acid battery can be restored to its original state.

The device for ~~moving~~ removing the membranous lead sulfate deposit according to the present invention is applicable to various kinds of lead-acid batteries. For instance, the device of the invention may suitably be used for passenger motor cars, motor tracks, buses, yachts, motor boats, fish boats, ships, farm machineries and implements, construction tools and machines, fork lift trucks, electric carts, road sweepers, electric wheelchairs, and backup power supplying systems for hospitals, police stations and fire stations, but the present invention does not contemplate imposing any limitation on applications and uses.

Hereinafter, the present invention will be further described in connection with an embodiment.

A lead-acid battery with a dedicated pulse generator (12 volts; 120 mW) incorporating a circuitry shown in FIG. 1 was discharged while a pulse current with a pulse width (T neg. in FIG. 2) of less than 1 μs was applied with a pulse rate of 10000 pulses per second to the battery. At that time, the value of the pulse current applied to the battery was set to 10 mA.

While applying the pulse current to the battery, alteration of the output voltage of the lead-acid battery was measured. In tandem with the measurement of the battery with the device of the invention, the performance of a common battery was

measured as a comparative example. The results of measurement are shown in Table 1 and FIG. 5.

As is apparent from Table 1 and FIG. 5, the lead-acid battery connected to the device of the invention could maintain its output voltage constant over a prolonged period of time in comparison with the comparative example. Furthermore, as shown in Table 2, the lead-acid battery with the device of the invention ~~could be~~ more ~~increased in~~ capacity than the comparative example. As a result, ~~it turned out that~~ the device of the invention contributes to extension of the life of the lead-acid battery.

In observing the interior of the lead-acid batteries discharged in the experiments, there were lead sulfate particles suspended in dilute sulfuric acid solution in the battery of the comparative example. Moreover, lead sulfate was ~~and~~ slightly deposited on the electrodes. However, growth of lead sulfate on the electrodes occurred rarely in the lead-acid battery using the device of the invention.

TABLE 1

(Unit: Output Voltage (volt))

DISCHARGE TIME (min.)	BATTERY WITH DEVICE OF THE INVENTION	BATTERY OF COMPARATIVE EXAMPLE
0	12.805	12.766
10	12.215	12.369
30	12.181	12.320
60	12.119	12.248
90	12.051	12.169
120	11.976	12.083
150	11.894	11.992
180	11.807	11.895
210	11.711	11.774
240	11.603	11.628
270	11.474	11.388
300	11.294	10.733
315	11.146	10.123
330	10.845	
345	10.075	
TOTAL	5 hr. 45 min.	5 hr. 15 min.

TABLE 2

	BATTERY WITH DEVICE OF THE INVENTION	BATTERY OF COMPARATIVE EXAMPLE
①AVERAGE VOLTAGE (DCV)	11.737	11.842
②DISCHARGE TIME (hour)	5.72	5.22
③LOAD RESISTANCE (Ω)	2.06	2.06
④AVERAGE DISCHARGE CURRENT (A) (①／③)	5.7	5.7
⑤ CAPACITY (AH) (④×②)	32.60	29.75
⑥ 30℃ REDUCED CAPACITY (AH) (⑤／0.97)	33.61	30.36
⑦ SPECIFICATION CAPACITY RATIO OF BATTERY (%) (⑥/28×100)	120	108

INDUSTRIAL APPLICABILITY

As is apparent from the foregoing disclosure, the device for removing membranous lead sulfate according to the present invention serves to concentrate the electrical charge in the surface layer of the membranous lead sulfate by the conductor skin effect, which is brought about by applying the pulse current with the short pulse width of less than 1 μs to the lead-acid battery. Thus, the device of the invention makes it possible to prevent the lead sulfate deposit on the electrode from exfoliating or falling off in clusters and also makes it possible for the lead sulfate to be resoluble into fine particles from the surface layer part near a boundary face between dilute sulfuric acid and itself.

Accordingly, the device of the invention makes it possible to ~~retrieve~~ revive the performance of a lead-acid battery deteriorated due to the lead sulfate deposit on the electrodes and block recrystallization of lead sulfate, consequently ~~to prevent~~ preventing growth of sulfation, so that the battery life of the lead-acid battery can be prolonged.

Furthermore, since the pulse current applied from the device of the invention is very faint in intensity, no noise is emitted to the outside environment.

~~DEVICE FOR REMOVING LEAD SULFATE FILM FORMED IN LEAD-ACID BATTERY~~

ABSTRACT

~~This invention seeks to provide a novel~~ A device is provided for removing membranous lead sulfate deposited on electrodes of a lead-acid battery by dissolving the lead sulfate into fine particles without causing the membranous lead sulfate to fall off or be suspended in the electrolytic solution, thus ~~to recover~~recovering the performance of the battery ~~in~~ from a deteriorated state and ~~prolong~~ prolonging the battery life. ~~This invention further seeks to provide a novel device for removing membranous lead sulfate deposit on the electrodes, which can emit little noise to the outside environment.~~ ~~To attain the objects as noted above according to the present invention, there is provided a~~ The device emits little noise to the outside and ~~for removing~~ removes the membranous lead sulfate deposited on electrodes of the lead-acid battery due to sulfation by ~~using a phenomenon~~ bringing about a conductor skin effect, whereby ~~of intensively dissolving~~ the surface layer of the membranous lead sulfate deposited on the electrodes is dissolved with ~~the~~ a pulse current having a short pulse width, ~~which~~ the device ~~is~~ being attached to a lead-acid battery and provided with a voltage detector, reference voltage generator, voltage comparator, oscillator, amplifier, waveform shaping circuit, negative pulse generator, and electrifying indicator. The pulse width of the pulse current is preferably 1 μs or less.